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PATENT SPECIFICATION

675,161

Date of Application and filing Complete Specification: Aug. 2, 1946.

No. 23092/46.

Application made in Netherlands on Aug. 7, 1945.

Complete Specification Published: July 9, 1952.

Index at acceptance:—Classes 7(i), C2; and 29, G31.

COMPLETE SPECIFICATION.

Improvements in or relating to Hot-Gas Reciprocating Engines

We, N.V. PHILIPS' GLOEILAMPENFABRIEKEN, a Limited Liability Company, organized and established under the laws of the Kingdom of the Netherlands, having our seat and office at Emmasingel, Eindhoven, Province of North Brabant, Kingdom of the Netherlands, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to hot-gas reciprocating engines.

It is known to construct the heat exchanger of hot-gas reciprocating engines in a manner such that the flow of the working medium is subdivided into a number of paths connected in parallel and the working medium is caused to exchange heat, in the subdivided state, by way of a wall of the heat exchanger. It is generally of paramount importance that the heat exchange should occur with a high efficiency, occupy little time and that little resistance should be opposed to the flow of the working medium which is in themal contact with the wall. These conditions are not satisfied or only to a minor extent fulfilled by most of the conventional constructions.

The object of the invention is to provide an improved hot-gas reciprocating engine comprising a heat exchanger in which the above-mentioned conditions are substantially met and in which hot-gas engine the clearance space is reduced.

The term "hot-gas reciprocating engine" is to be understood to mean a reciprocating engine for converting heat into mechanical energy, or mechanical energy into heat energy, in which a constantly gaseous working medium of invariable composition is taken round an open or a closed thermodynamic cycle. The term hot-gas reciprocating engine is thus to be understood to include a refrigerating machine operating according to the reversed hot-gas engine principle. The wall through which the working medium is required to exchange heat will constitute a partition between two media, between which the exchange of heat is required to take place. This wall may constitute the partition between the working medium of the engine and the combustion gases of a heating means, e.g., a burner, or between the working medium and another medium which may be gaseous or liquid and which has a cooling function.

According to the invention, a hot-gas reciprocating engine comprising a heat exchanger provided with a cylindrical wall through which an exchange of heat between two media is required to take place, is characterized in that one or each of the media is supplied to the wall through which heat exchange is required to take place by way of a large number of main supply channels extending in the same general direction and after making heat-exchanging contact with said wall is carried off by way of a number of main outlet channels extending in the same general direction, the supply and outlet channels opening within the heat exchanging area of the said wall and the path traversed by the medium between a supply channel and an outlet channel having a maximum length of $\frac{1}{3}$ of the height of the heat-exchanging part of the said wall.

More usually, in a hot-gas engine for converting heat energy into mechanical energy, only the working medium will be so supplied to and carried off from the heat exchanger and in a refrigerating apparatus operating according to the reversed hot-gas engine principle, only the gas or liquid required to be cooled will be so supplied to and carried off from the heat exchanger.

The term "cylindrical" when used to apply to a wall is to be understood to mean that the wall has a surface which may be

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ERRATA

SPECIFICATION NO. 675161

Page 1, line 39, after "heat" insert "energy".

Page 2, line 28, for "advantages" read "advantage".

Page 3, line 47, for "direction" read "directions".

Page 4, line 15, for "Fig" read "Figs".

THE PATENT OFFICE,
1st August, 1952

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It is known . . . ex-changer of hot-gas reciprocating engines in a manner such that the flow of the working medium is subdivided into a number of paths connected in parallel and the working medium is caused to exchange heat, in the subdivided state, by way of a wall of the heat exchanger. It is generally of paramount importance that the heat exchange should occur with a high efficiency, occupy little time and that little resistance should be opposed to the flow of the working medium which is in themal contact with the wall. These conditions are not satisfied or only to a minor extent fulfilled by most of the conventional constructions.

The object of the invention is to provide an improved hot-gas reciprocating engine comprising a heat exchanger in which the above-mentioned conditions are substantially met and in which hot-gas engine the clearance space is reduced.

The term "hot-gas reciprocating engine" is to be understood to mean a reciprocating engine for converting heat into mechanical energy, or mechanical energy into heat energy, in which a constantly gaseous working medium of invariable composition is taken round an open or a closed thermodynamic cycle. The term hot-gas reciprocating engine is thus to be understood to include a refrigerating machine operating [Pric

reciprocating engine comprising a heat exchanger provided with a cylindrical wall through which an exchange of heat between two media is required to take place, is characterized in that one or each of the media is supplied to the wall through which heat exchange is required to take place by way of a large number of main supply channels extending in the same general direction and after making heat-exchanging contact with said wall is carried off by way of a number of main outlet channels extending in the same general direction, the supply and outlet channels opening within the heat exchanging area of the said wall and the path traversed by the medium between a supply channel and an outlet channel having a maximum length of $\frac{1}{3}$ of the height of the heat-exchanging part of the said wall.

More usually, in a hot-gas engine for converting heat energy into mechanical energy, only the working medium will be so supplied to and carried off from the heat exchanger and in a refrigerating apparatus operating according to the reversed hot-gas engine principle, only the gas or liquid required to be cooled will be so supplied to and carried off from the heat exchanger.

The term "cylindrical" when used to apply to a wall is to be understood to mean that the wall has a surface which may be

considered to be generated by the movement of a straight line such that a point on the line describes a closed, continuous curve (for instance a circle) or describes a closed line having discontinuities (for instance a zig-zag line) the closed line having substantially the form of a continuous curve (for instance a circle) and the straight line remaining parallel throughout its movement to a line coincident with its initial position.

With the use of a large number of parallel-connected paths for the medium, which paths are short compared with the height of the heat-exchanging part of said wall, resistance to flow is small and the speed at which the medium traverses the heat exchanger is low, which is beneficial to the heat exchange. A wall with which a medium is in heat exchanging contact may be smooth or it may be provided with projections e.g., ribs. Ribs for increasing the heat transfer are known *per se*. Owing to the satisfactory properties of the heat exchanger, however, it is sufficient to use shorter projections than those used in conventional heat exchangers. Apart from the advantages of saving material, the additional advantage is obtained that the clearance space in the hot-gas engine is small. By reducing the clearance space of a hot gas engine, the efficiency of the engine is raised.

In order to reduce the height of the wall over which the heat transfer takes place, the supply and outlet channels will preferably be so arranged that each supply channel is intermediate two outlet channels and *vice versa*. Further it may be advisable that at least one of the linear cross dimensions of the supply and of the outlet channels should vary gradually.

In order that the invention may be more clearly understood, and readily carried into effect, it will now be described more fully with reference to the accompanying drawing.

Fig. 1 is a longitudinal sectional view of the cylinder head of a hot-gas engine according to the invention provided with a cylindrical outer wall through which exchange of heat between two media is to take place, Fig. 2 being a perspective view of part of the cylinder wall.

Fig. 3 is a longitudinal sectional view of an alternative construction of the cylinder head of a hot-gas engine according to the invention, Figs. 4*a*, 4*b* and 4*c* being perspective views of parts thereof.

Fig. 5 illustrates a further alternative construction, and Fig. 6 is a developed view of the inner side of the outer wall of the cylinder head shown in Fig. 5 through which outer wall exchange of heat between two media is required to take place.

Figs. 1 and 2 represent diagrammatically the cylinder head of a hot-gas engine of which 11 is a cylindrical outer wall through which an exchange of heat is required to take place and 10 is the cylinder wall in which is movable a displacer. The cylinder wall 10 is spaced slightly apart from the outer wall 11 and, as is shown in Fig. 2, comprises channels 12, 13, 14 and 15, all of which extend parallel to the axis A—A of the outer wall 11. The channels 12 and 14 serve for the supply of the medium to be heated when due to the upward movement of the displacer the medium to be heated flows from the head downwards through the heater, the channels 13 and 15 serve for the outlet thereof. The outer surface of the outer wall 11 is heated during operation of the engine by means of a burner (not shown). As appears particularly from Fig. 2 each of the channels 12 and 14 are arranged intermediate two of the outlet channels 13 and 15. All these channels are open at the outside. Owing to this a communication exists between the supply and outlet channels through the intermediary of the space between the inner surface of the outer wall 11 and the outer surface of the cylinder wall 10. The path followed by the gases is shown in Fig. 2 in regard to the channels 12 and 13, from which it appears that in this form of construction the paths of the gas having a length *f* extends substantially normal to the cylinder axis A—A of the cylinder wall 10. From the drawing, it also appears that the length *f* is very small with respect to the height *d* of the wall 11 through which exchange of heat is required to take place. In this case, furthermore, practically the whole surface of the wall 11 partakes in the exchange of heat. In the way set out above it is ensured that a very large surface, which is in heat-exchanging contact with a medium to be heated, contacts over very short paths with the medium to be heated, though the diameter *l* of the heat-exchanging wall 11 is comparatively small. As appears from the drawing each of the channels 12, 13, 14 and 15 are such that the cross section of each channel decreases with increase in distance from the point at which the medium to be heated is supplied thereto or decreases with increase in distance from the point of out-flow, respectively.

Figs. 3 and 4*a*, *b* and *c*, represent diagrammatically an alternative construction of the cylinder head of a hot-gas engine, the manufacture of the cylinder wall, which in this case is denoted by the reference number 16, being simplified. In fact, the supply and outlet channels 17, 18, 19 and 20 are provided in a simpler manner than the channels 12, 13, 14 and

15 shown in Figs. 1 and 2, since in the present construction three cylindrical walls are provided, firstly the outer wall 24 through which exchange of heat is required to take place, secondly the cylinder wall 16 and thirdly a wall 21 which directly engages the cylinder wall 16 is slightly spaced apart from the wall 24 and comprises elongated rectangular slots 22, the pitch of which corresponds to the pitch of the channels in the cylinder wall 16. Figs 4*b* and 4*c* clearly show the manner in which the walls 21 and 16 are formed. For simplification, the circulation of the medium is shown in conjunction with Figs. 4*b* and 4*c*. By varying the width of the channels 23 between the slots 22 the length of the path of the medium is variable. As appears from Fig. 4*a*, the outer surface of the outer wall 24 is provided with ribs 25 and the inner surface thereof is furnished with continuous ridges 26 by which the contact between the medium to be heated and the outer wall 24 is rendered still more intimate.

Figs. 5 and 6 show a further alternative construction of the cylinder head of a hot-gas engine according to the invention. In this embodiment a very large number of small cylindrical projections are provided on the inner side of the outer cylindrical wall 30 of the engine. The projections are provided over a zig-zag part 31 of the wall 30 as is shown clearly in the figures. In Fig. 6 the inner side of the wall 30 comprising these cylindrical projections is shown as a developed surface. The cylinder head also in this case contains a cylinder wall within the wall 30, which cylinder wall however, is not represented for the sake of simplicity. Owing to the presence of the cylinder wall, the gases to be heated flow when the displacer (not represented) moves upwards between the cylinder wall and the outer wall 30 through which exchange of heat is required to take place in the direction indicated by the arrows in Fig. 5 so that effectively, a large number of auxiliary channels are provided arranged in groups which extend in various directions between the cylindrical projections the channels in each group being mutually parallel. The gases will follow the paths of least resistance and will substantially follow the paths indicated by the arrrows in Fig. 5. In this construction also, each main supply channel 32 is intermediate two main outlet channels 33. This construction has the advantage that a very large heat exchanging surface is obtainable within a definite diameter *l*, the length *m* of the paths traversed by the gas over the heat exchanging part of the wall 30 between an inlet channel 32 and an outlet channel 33 being smaller than $\frac{1}{3}$ of the height *k* of the wall 30. The small cylindrical projections may be provided on one or each side of the wall through which heat exchange is required to take place.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A hot-gas reciprocating engine comprising a heat exchanger provided with a cylindrical wall through which an exchange of heat between two media is required to take place, characterized in that one or each of the media is supplied to the wall through which heat exchange is required to take place by way of a large number of main supply channels extending in the same general direction and after making heat-exchanging contact with said wall is carried off by way of a number of main outlet channels extending in the same general direction, the supply and outlet channels opening within the heat-exchanging area of said wall and the path traversed by the medium between a supply channel and an outlet channel having a maximum length of $\frac{1}{3}$ of the height of the heat-exchanging part of said wall.

2. A hot-gas engine as claimed in Claim 1, characterized in that the supply and outlet channels are arranged so that each supply channel is intermediate two outlet channels.

3. A hot-gas engine as claimed in Claim 1 or 2, characterized in that the path traversed by the medium between a supply channel and an outlet channel is substantially at right angles to the cylinder axis of said wall.

4. A hot-gas engine as claimed in any of Claims 1 to 3, characterized in that at the inner side of said wall and at a distance apart therefrom is provided a second cylindrical wall comprising openings for the inlet and outlet channels, the medium, after leaving the inlet channels making intimate contact with the wall through which heat exchange is required to take place and then being carried off through the outlet channels.

5. A hot-gas engine as claimed in Claim 4, characterized in that the second cylindrical wall is surrounded by a third cylindrical wall which is provided with slots the pitch of which corresponds to the pitch of the main channels in the second wall.

6. A hot-gas engine as claimed in any of Claims 1 to 5 characterized in that the inner side of the wall through which heat exchange is required to take place is provided with annular ridges.

7. A hot-gas engine as claimed in Claim

1 or 2, characterized in that on one or each side of the cylindrical wall through which heat exchange is required to take place a large number of small cylindrical projections are provided to form auxiliary channels communicating between the main supply and outlet channels.

8. A hot-gas engine as claimed in any of the preceding Claims characterized in that at least one of the linear cross dimensions of the main supply and of the main outlet channels varies gradually.

9. A hot-gas engine comprising heat exchanging means substantially as described with reference to Figs. 1 and 2, Fig. 3, 4*a*, 4*b* and 4*c* or Figs. 5 and 6 of the accompanying drawings.

Dated this 2nd day of August, 1946.

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Century House,
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Agents for the Applicants.

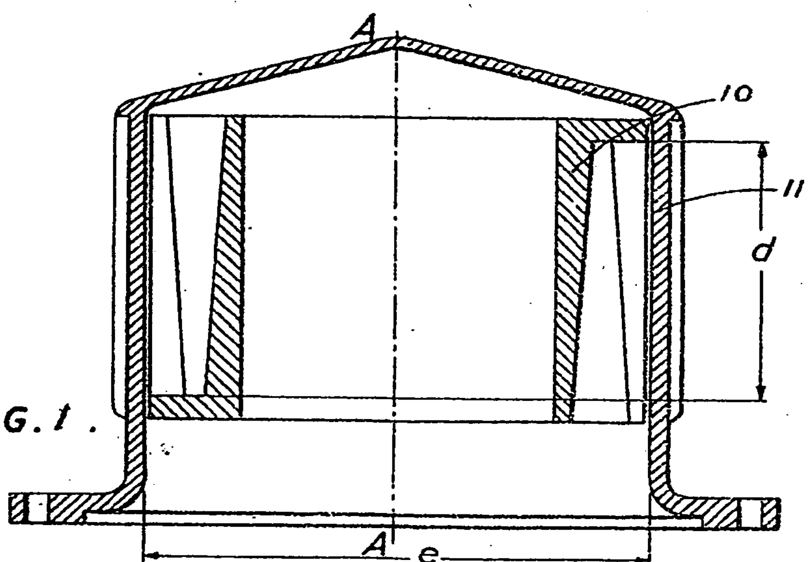

FIG. 1.

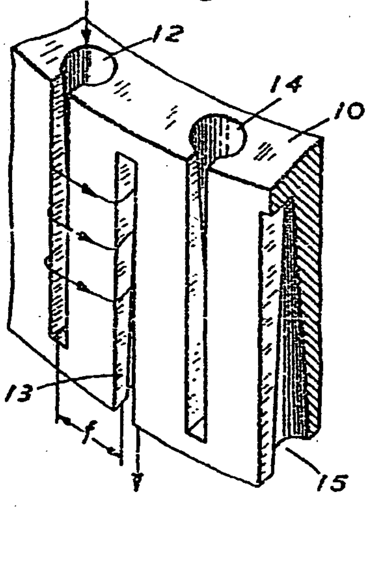

FIG. 2.

675,161 COMPLETE SPECIFICATION
3 SHEETS

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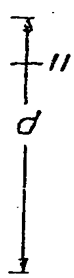
SHEETS 1 & 2



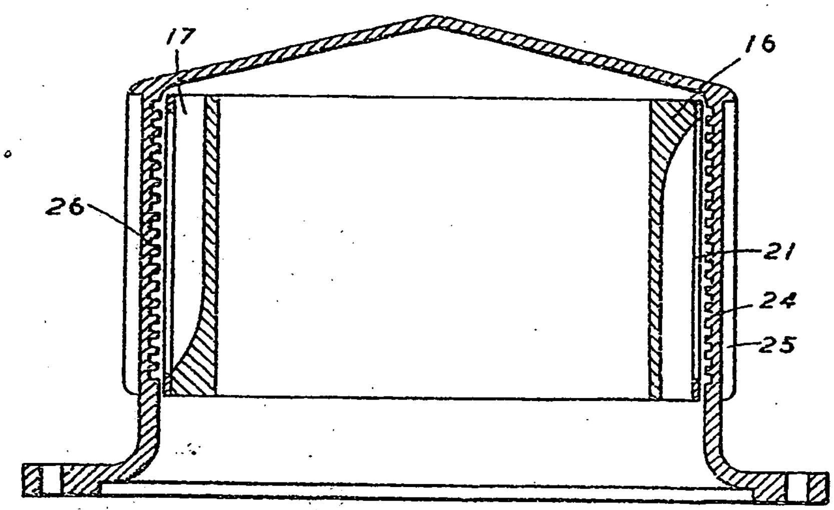
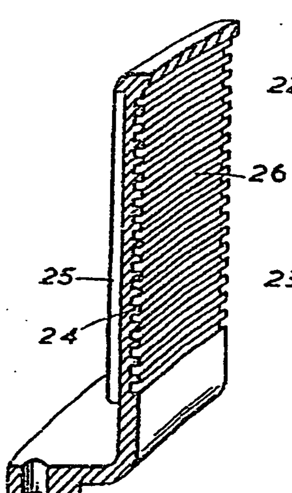
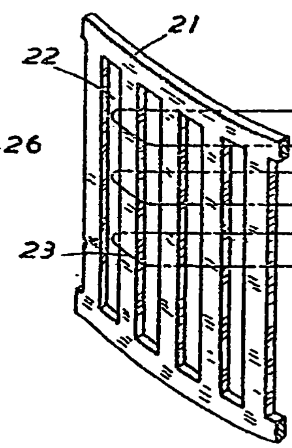


FIG. 3.





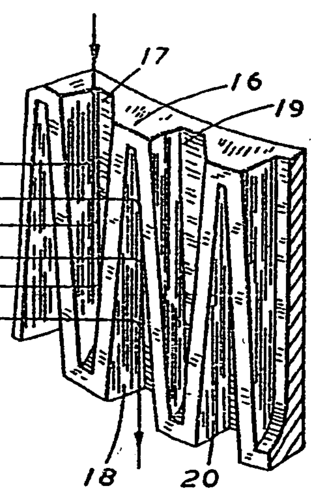


FIG. 4a. FIG. 4b. FIG. 4c.

675,161 COMPLETE SPECIFICATION
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SHEETS 1 & 2

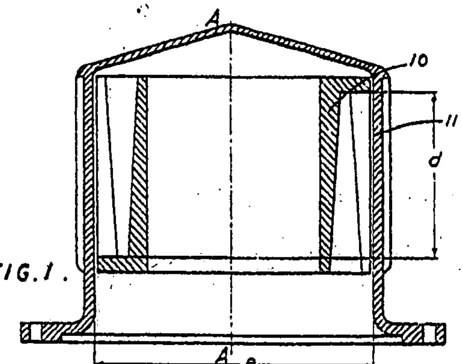

FIG. 1.

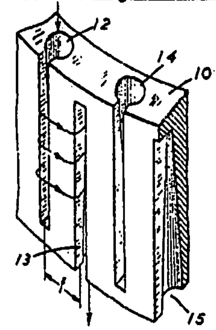

FIG. 2.

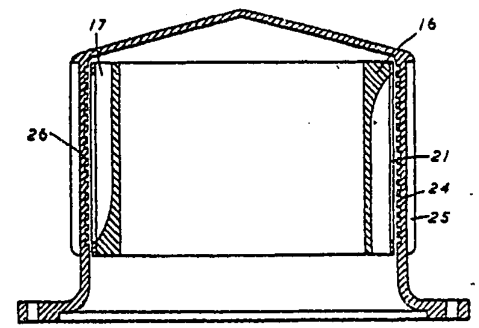

FIG. 3.

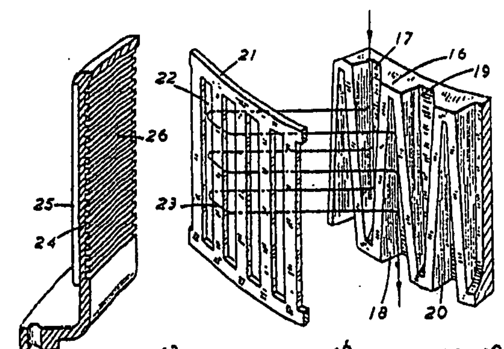

FIG. 4a. FIG. 4b. FIG. 4c.

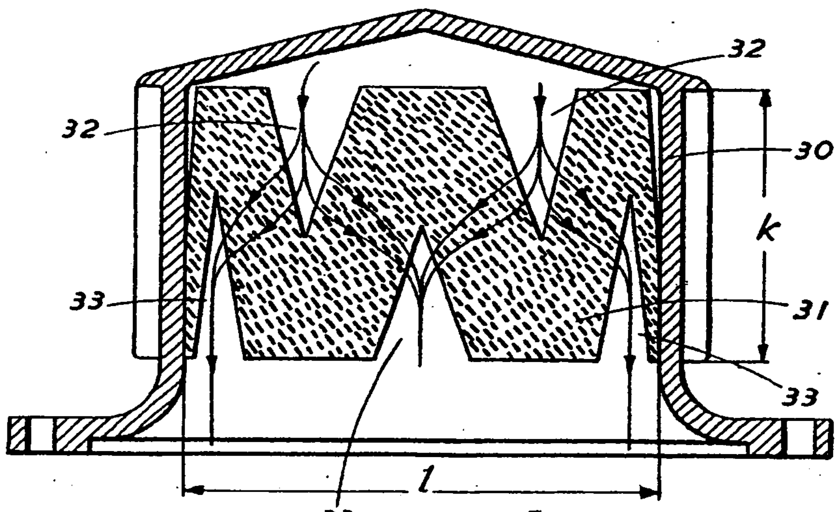

FIG. 5.

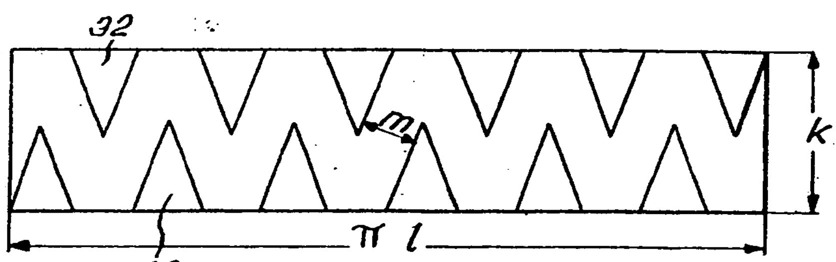

FIG. 6.

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